2812

CP-3400
I-C
Copy 24A

[redacted]

Contract No. W-7401-eng-37

- - -

Physics Division

- - -

INSTRUMENT SECTION
W. P. Jesse, Section Chief

DECLASSIFIED Per Letter Instructions Of TID-1003
3-5-52 [signature] SUPERVISOR CENTRAL FILES
ORNL

GAMMA MONITORING SYSTEM

(Mark 10, Model 50, Type G)

Manuel Holtzman

December 11, 1945

[redacted]

Report Received: January 10, 1946
Figures Received: January 18, 1946
Issued:

[redacted]

[redacted]

GAMMA MONITORING SYSTEM

(Mark 10, Model 50, Type G)

Manuel Holtzman

December 11, 1945.

INTRODUCTION

The presence of high gamma radiation, with its attendant danger to human life, necessitates a system designed to detect this radiation and to give warning when the radiation exceeds permissible tolerance levels. Such a monitoring system will be described in this report.

THEORETICAL CONSIDERATIONS

It is not the purpose of this paper to delve into the theory of gamma radiation. For the reader who desires this additional information, a bibliography of books discussing gamma radiation may be found in the back section of this report (References 1, 2, 3, and 4).

GENERAL REQUIREMENTS

In order to develop an efficient system, certain general requirements are suggested. These are the factors that shape the development channels.

1. Should be a.c. operated,
2. Stability with respect to line voltage changes, to voltmeter drift, and to alarm circuit drift should be high,
3. Sensitivity to line transients and disturbances should be of a low order,
4. Sensitivity to mechanical shock should also be of a low order.
5. Zero setting of the system should be possible in the presence of strong gamma radiation,
6. Unattended operation should be possible over long periods of time.

GENERALIZED SYSTEM DESCRIPTION

In order to simplify the discussion of this instrument, a general description of the entire system will be presented first.

[redacted]

[redacted]

This system contains an ionization chamber connected to a Victoreen VE124 tube used as an electrometer tube. The VE124 tube feeds directly to a 6J6 used as a balanced type voltmeter. One side of the 6J6 feeds into a 2D21 Thyratron tube which operates a relay connected to a visual alarm. Because of chattering, the relay will also act as an audible alarm. A 5Y3GT tube is used as a full wave rectifier followed by VR150 and VR105 regulator tubes in cascade connection.

Input voltage sensitivity is approximately .8 of a volt full scale, while current sensitivity is of the order of 8×10^{-12} amperes full scale.

DETAILED SYSTEM DESCRIPTION

The Chamber.

The chamber is built in a cylindrical form of approximately 1 liter volume. The chamber material is 1/8 inch bakelite. An "AN" Amphenol connector is placed at one end plate of the bakelite cylinder with the chamber center electrode connected to the Amphenol connector. The center electrode is a single solid wire extending to within a half inch of the opposite cylinder end plate. An aquadag conducting coating covers the inside of the chamber. A non-coated area of approximately 3/8 inch extends around the Amphenol connector to insulate the connector from the aquadag coating. The aquadag coating connects to an external lead that terminates in a banana plug. Because of its conductivity, the aquadag coating acts as the outer chamber electrode.

Figure (1) shows the chamber and connections to the electrometer tube.

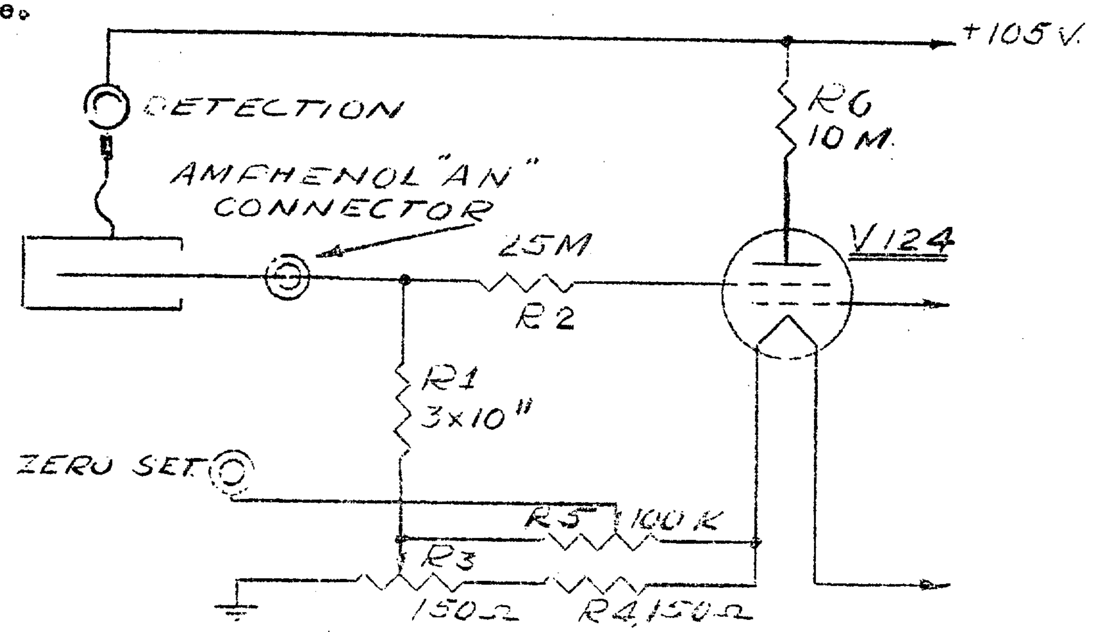


Figure 1.

[redacted]

The chamber is connected to the Victoreen VE124 tube through an Amphenol "AN" connector and a 25 megohm resistor. A 3×10^{11} ohm resistor (R_1) acts as a load resistor for the chamber. The voltage drop across R_3 and R_4 is utilized to bias the grid of the VE124 tube.

In the presence of a strong radiation field, any attempt to zero set the system by removing the positive voltage from the chamber and connecting the chamber outer electrode to the 150 ohm potentiometer, is not feasible. Even a small grid current flowing through the 3×10^{11} ohm resistor produces a small voltage at the chamber. This voltage is sufficient to produce ionization currents in the chamber in a strong radiation field.

Two methods of obtaining a practical zero set were suggested. One, the removal of the chamber from the electrometer tube circuit by means of a well-insulated switching arrangement; and two, the addition of a small bucking voltage to oppose the voltage created by grid and stray collection currents. As extreme accuracy was not a prime objective, the second method was used.

Current flowing through potentiometer R_5 (100K ohms) produces a voltage in opposition to the voltage created by the grid current. During the "zero set" operation the banana plug is removed from the "detection" receptacle and placed in the "zero set" receptacle. The instrument may then be "zero set" by adjusting potentiometer R_3.

A source is brought close enough to the chamber to produce a reading of approximately t en times full scale with the system in the "detection" position. If the bucking voltage potentiometer is correctly adjusted, the system may now be changed to the "zero set" position and a difference of only 1% of full scale will be noted if the source is removed. This variation is permissible.

<u>The Electrometer Tube.</u>

As can be seen from Figure (2), the VE124 (Victoreen) is connected as an electrometer tube (References 5 and 6) using the second grid as the control element.

The importance of the Victoreen tube in this circuit can not be minimized. The VE124 tube was developed for d.c. circuits requiring extremely high grid resistance and low grid currents. Among its most important features are extremely low filament current (10 milliamperes at 1.25 volts), and low accelerator and plate voltages. For more detailed information reference should be made to a paper describing this tube presented by Victoreen Instrument Company (Reference 7).

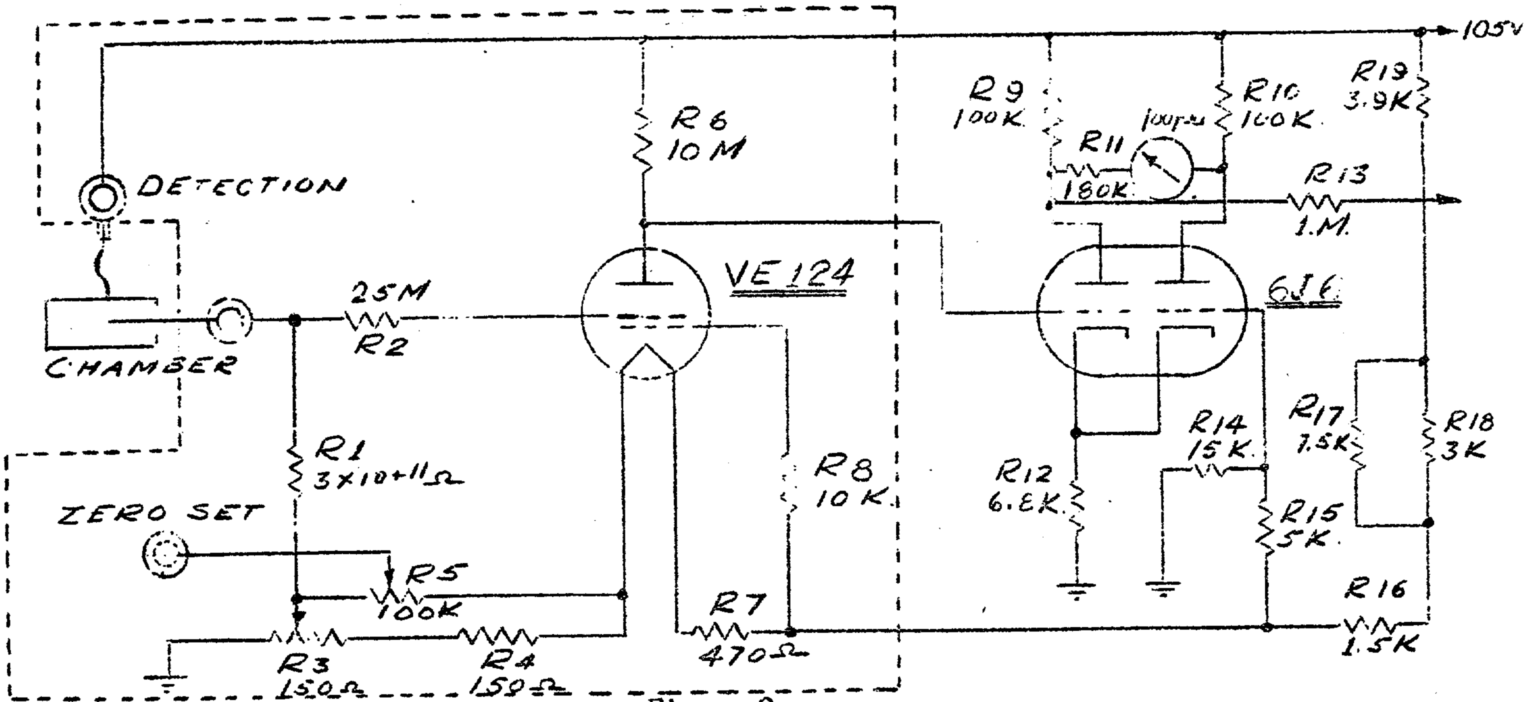


Figure 2.

In order to gain stability, the filament current is regulated. The filament current of 11 milliamperes is obtained from the regulated 105 volt "B" supply. From series resistors R_3 and R_4 the necessary grid bias for the VE124 tube is obtained. Accelerator voltage for the first grid is also supplied from the series filament resistor network. Plate voltage is obtained from the regulated 105 "B" voltage through a 10 megohm load resistor.

This system is found highly responsive to line transients and disturbances; the average line transient moving the meter needle over full scale. In order to eliminate this condition, a 25 megohm resistor is placed in series with the grid. As line transients are of R.F. nature, then to the high frequencies present in line transients the tube element capacities present a definite impedance. This impedance is of a much lower order than the 25 megohm resistance. Therefore, high frequency currents present in the grid circuit will dissipate in the 25 megohm resistor, with very little of the disturbing voltages appearing across the tube.

This tube is also photo-sensitive. In order to shield the tube from light fluctuations and from stray static field, the tube and its input circuit are placed within a small cabinet. In Figure (2), all apparatus included within the dotted line is placed within the small cabinet.

The Voltmeter Tube.

The 6J6 miniature tube is used in a balanced type voltmeter circuit (Reference 8) as shown in Figure (3).

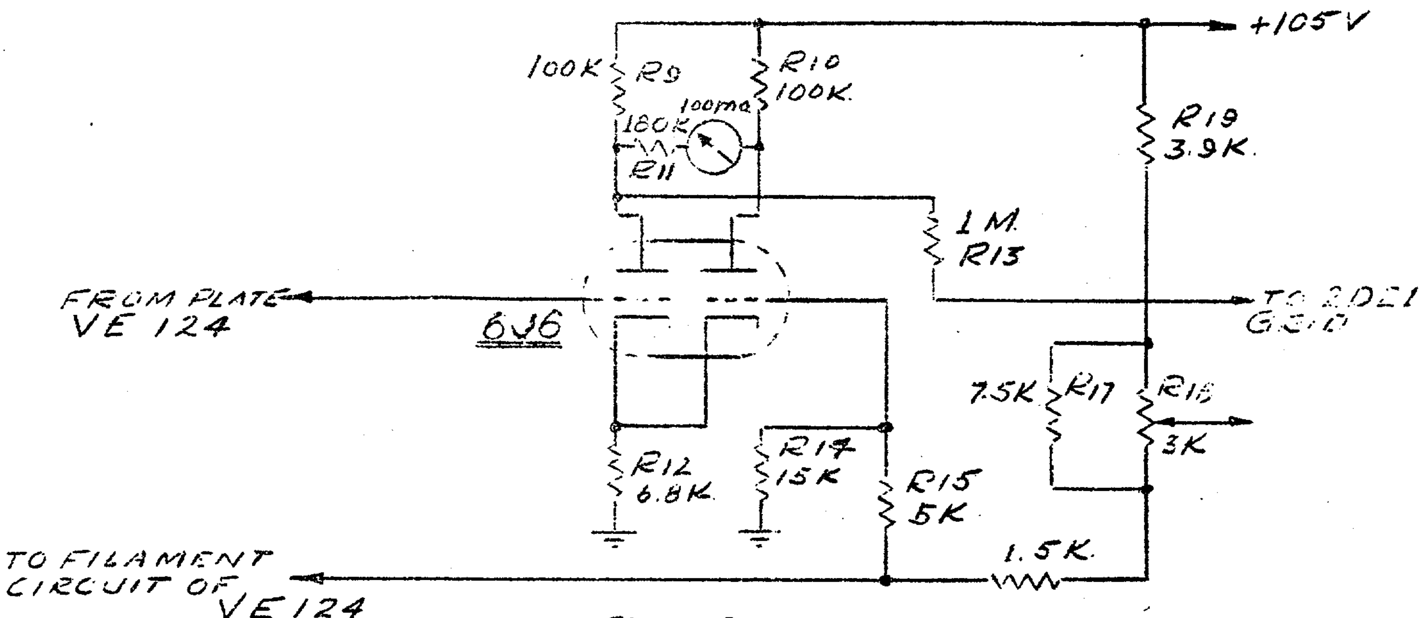


Figure 3.

The two sections of the tube are self-biased by means of a cathode resistor R_{12}. The second section grid obtains its balancing voltage from an additional voltage divider R_{14} and R_{15}. Signal voltage for the first grid of the voltmeter tube is obtained by direct coupling from the plate of the electrometer tube. With no signal input and the instrument at zero, the grid voltages are +7.15 volts, the cathode voltage is +8.8 volts, and the plates are +45 volts each with respect to ground. Voltage change available at the plates of the voltmeter tube is approximately 20 volts for full scale deflection of the 100 ua meter.

The Alarm Circuit.

Use is made of a new miniature thyratron tube, the 2D21, in the alarm circuit of the system as shown in Figure (4).

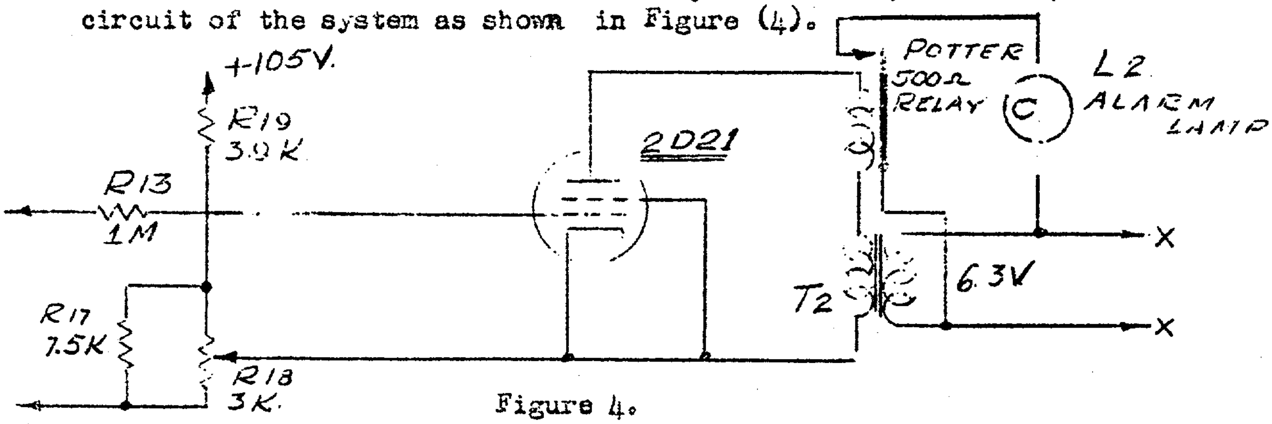


Figure 4.

Signal voltage is carried from the first plate of the 6J6 voltmeter tube to the first grid of the 2D21 thyratron tube through the one megohm decoupling resistor R_{13}. The cathode voltage is obtained from the potentiometer R_{18}. Variation of R_{18} determines the operating point at which the tube will fire. An a.c. voltage of approximately 110 volts is supplied from transformer T_2 and it is the presence of this a.c. plate voltage that quenches the thyratron tube. A six volt pilot lamp is used as the alarm lamp. An audible alarm is obtained due to the chattering of the 500 ohm Potter relay in the plate circuit of the 2D21 tube.

<u>The Power Supply.</u>

The power supply differs from the highly conventional circuits used in the past only in the use of two VR tubes in cascade. The cascading of the two VR regulator tubes, as shown in Figure (5) affords a high degree of regulation.

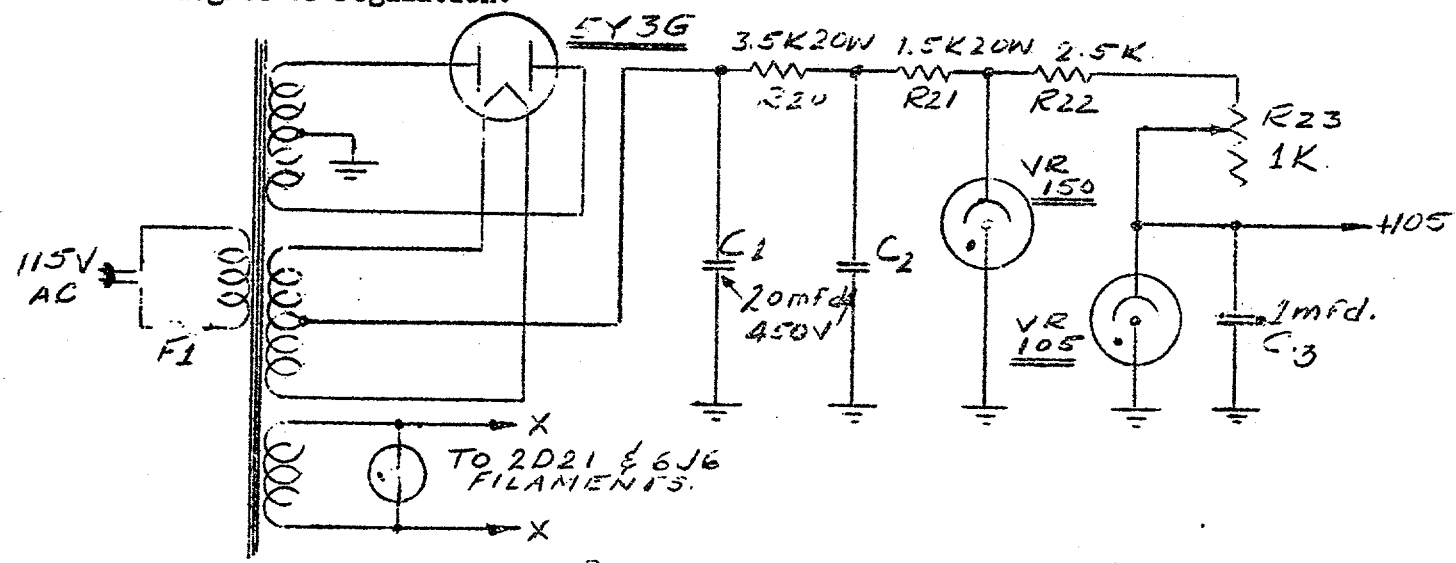


Figure 5.

A typical plot of VR voltage versus VR current is shown in Figure (6).

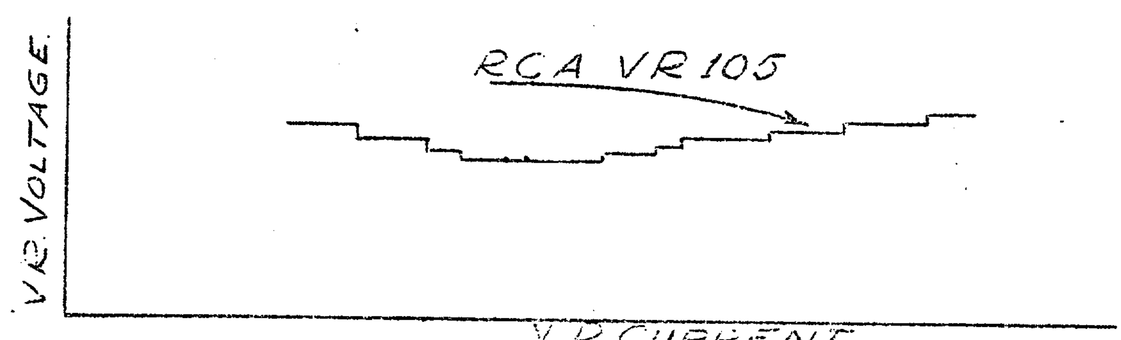


Figure 6.

This curve shows a number of small discontinuities. Potentiometer R_{23} is adjusted to place the operating current of the VR105 tube in the middle of the plateau which is present between two of these discontinuities. The VR105 characteristics may change as the tube ages. The adjustment of potentiometer R_{23} makes it possible to compensate for changes that may occur. A line voltage change of 30 volts produces no visible change of VR output voltage when VR output voltage is read with a 150 volt full scale meter.

Power supply ripple is also reduced to a very low figure by use of the cascaded VR tubes. Ripple voltage at the output of the VR150 tube is approximately .01 of a volt, while at the output of the VR105 tube it is approximately .001 of a volt.

SUMMARY

This instrument is found to come well within requirements desired with respect to stability in presence of line voltage changes. The following data show the effect of line voltage changes on the zero set and the instrument reading.

Line Voltage	At Zero Set % of Full Scale	At 63.5% of Full Scale
100	-0.5	63.5
105	0	63.5
110	0	63.5
115	-0.5	63.5
120	-0.8	63.8
125	-1.0	64.2
130	-1.0	64.4

Zero set drift is less than 1% of full scale in 24 hours, providing the VE124 has been properly aged. Operation under normal conditions of about seven days will properly age the VE124 tube. After curing, any interruption to the filament current will necessitate an additional stabilizing period of approximately two hours before the circuit is used.

Emphasis is placed on the ability of the two cascaded VR tubes to produce a high degree of regulation. It is this fact, plus the unusually small filament current of 10-12 milliamperes required by the Victoreen VE124 tube that makes possible the attainment of the exceptional stability shown by this instrument.

As explained in the section devoted to the electrometer tube, the sensitivity of this instrument to line transients and disturbances is low.

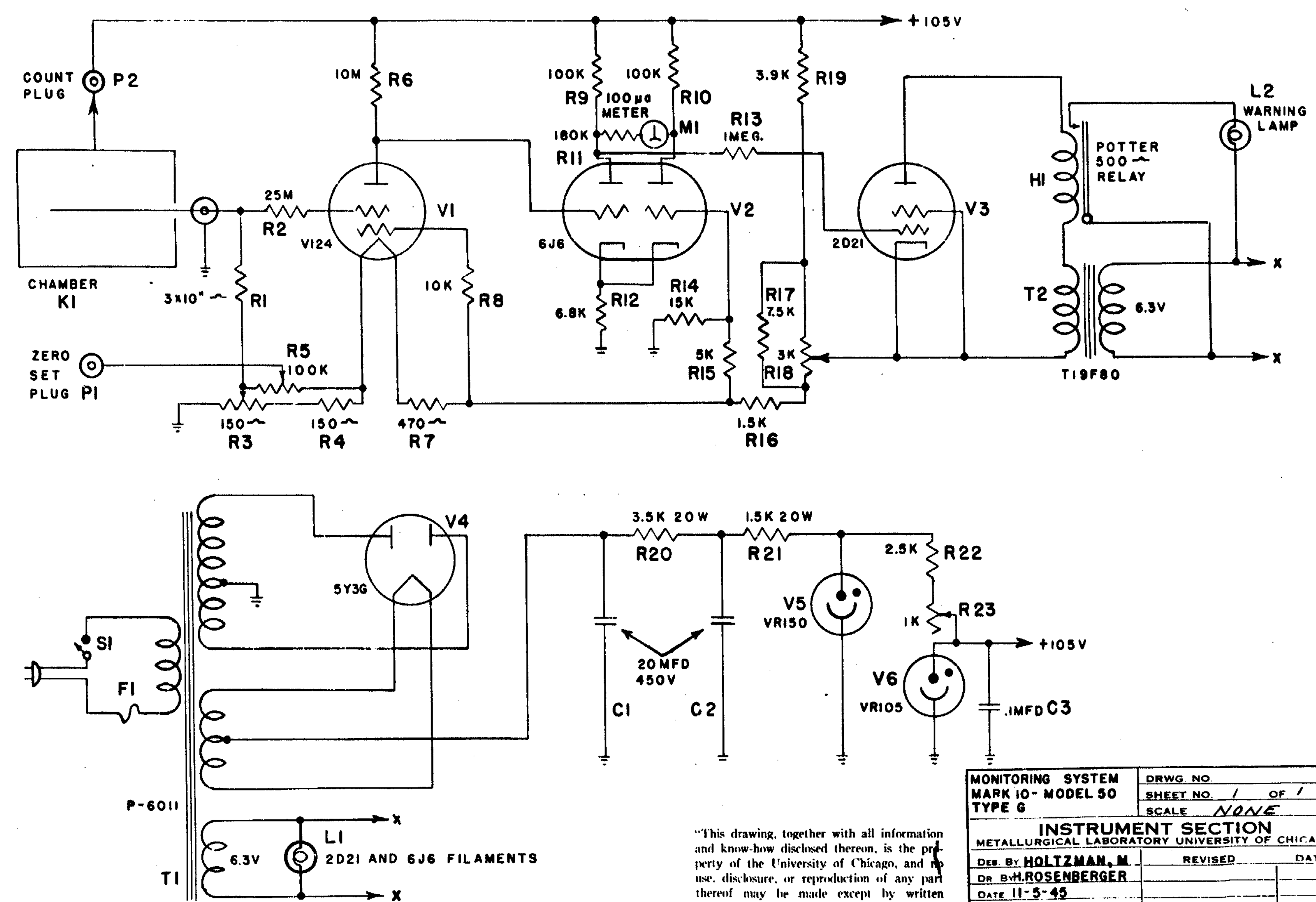
This instrument is not sensitive to ordinary slight mechanical shocks and vibrations. A direct blow on the instrument case itself is necessary to deflect the meter pointer.

The alarm circuit may be set to operate at any point on the meter scale. For gamma ray intensities of 0.1 r/8 hour day, the instrument will read 40% of full scale.

This instrument is designed for continuous service. Where extreme accuracy is required, however, the zero set should be checked each day.

ACKNOWLEDGMENT

Acknowledgment is made by the writer to Wendell Bradley for the original general designs and suggestions used in the development of this instrument.



"This drawing, together with all information and know-how disclosed thereon, is the property of the University of Chicago, and no use, disclosure, or reproduction of any part thereof may be made except by written authorization of the University of Chicago."

MONITORING SYSTEM MARK 10- MODEL 50 TYPE G	DRWG. NO. SHEET NO. 1 OF 1 SCALE NONE
INSTRUMENT SECTION METALLURGICAL LABORATORY UNIVERSITY OF CHICAGO	
DES. BY HOLTZMAN, M	REVISED / DATE
DR. BY H. ROSENBERGER	
DATE 11-5-45	
APP. BY HOLTZMAN, M	

REFERENCES

1. Pollard and Davidson, Applied Nuclear Physics, pps. 128-132, 1942, John Wiley and Sons.

2. Rasseti, F., Elements of Nuclear Physics, pps. 14-26 and pps. 76-98, 1936, Prentice-Hall.

3. Stranathan, J. D., The "Particles" of Modern Physics, pps. 315-361, 1942, Blakiston (Philadelphia).

4. Richtmyer and Kennard, Introduction to Modern Physics, pps. 577-582, 1942, McGraw-Hill.

5. Laws, F. A., Electrical Measurements, pps. 258-260, 1938, McGraw-Hill.

6. Strong, J., Procedures in Experimental Physics, pps. 413-422, 1943, Prentice-Hall.

7. Victoreen Instrument Company, "VX124B Electrometer Tube", September 15, 1944.

8. Reich, H. J., Theory and Applications of Electron Tubes, pps. 555-580, 1939, McGraw-Hill.

PARTS LIST

Item	Quantity	Part Number	Description	Manufacturer
1	1	V_1	VE124 tube	Victoreen
2	1	V_2	6J6	Sylvania
3	1	V_3	2D21	RCA
4	1	V_4	5Y3G	RCA
5	1	V_5	VR150	General Electric
6	1	V_6	VR105	General Electric
7	1	T_1	Power transformer	Stancor P6011
8	1	T_2	Filament transformer	Thordarson T19F80
9	1	R_1	3×10^{11} ohms	Victoreen
10	1	R_2	25 megohm ½ watt	Centralab
11	1	R_3	150 ohm potentiometer	Centralab
12	1	R_4	150 ohm, 1 watt	Allen-Bradley
13	1	R_5	100,000 ohm potentiometer	Centralab
14	1	R_6	10 megohm, ½ watt	Allen-Bradley
15	1	R_7	470 ohm, 1 watt	Allen-Bradley
16	1	R_8	10,000 ohm, ½ watt	Allen-Bradley
17	2	R_9, R_{10}	100,000 ohm, ½ watt	Allen-Bradley
18	1	R_{11}	180,000 ohm, ½ watt	Allen-Bradley
19	1	R_{12}	6,800 ohm, ½ watt	Allen-Bradley
20	1	R_{13}	1 megohm, ½ watt	Allen-Bradley
21	1	R_{14}	15,000 ohm, ½ watt	Allen-Bradley
22	1	R_{15}	5,000 ohm, ½ watt	Allen-Bradley
23	1	R_{16}	1,500 ohm, 1 watt	Allen-Bradley
24	1	R_{17}	7,500 ohm, 1 watt	Allen-Bradley
25	1	R_{18}	3,000 ohm, 1 watt	Allen-Bradley
26	1	R_{19}	3,900 ohm, 1 watt	Allen-Bradley
27	1	R_{20}	3,500 ohm, 20 watt	Ohmite
28	1	R_{21}	1,500 ohm, 20 watt	Ohmite
29	1	R_{22}	2,500 ohm, 10 watt	Ohmite
30	1	R_{23}	1,000 ohm potentiometer	Centralab
31	1	C_1, C_2	double 20 mfd. filter condenser 450 volts	Aerovox
32	1	C_3	.1 mfd., 600 volts	Aerovox
33	1	M_1	100 microamp. meter	Electro-Tec
34	1	S_1	6 ampere, 125v DPST	Arrow-Hart-Hegeman
35	1	F_1	3 AG-3 ampere fuse	Buss
36	2	L_1, L_2	6.3 volts bayonet pilot	General Electric

Item	Quantity	Part Number	Description	Manufacturer
37	2	P_1, P_2	Banana plug receptacles	National Radio
38	6		Octal tube sockets	Amphenol
39	2		6 volt bayonet-type pilot 1 ampere assembly	Drake
40	1		110 volt a.c. receptacle	Amphenol